VLC-based light-weight portable user interface for in-house applications

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***Abstract*—Advances in solid-state lighting have overcome common limitations on optical wireless such as power needs due to light dispersion. It's been recently proposed the modification of lamp's drivers to take advantages of its switching behaviour to include data links maintaining the illumination control they provide. In this paper, a remote access application using visible light communications is presented that provides wireless access to a remote computer using a touchscreen as user interface.**

***Index Terms*—Visible Light Communications (VLC), optical wireless communications, solid-state lighting, Light Emitting Diode (LED)**

I. Introduction

Mobility has become a key factor on the design of any device. With processing capabilities exceeding the needs for most applications, end-users look for mobile devices that do not rely on wired connections to operate. Cellular phones, PDAs, video/audio players, TVs, etc. are intended to access the data anytime, anywhere. Thus, wireless communications appear as an important technology to ensure data access and connectivity on any location within the target application's range.

RF communications are, by far, the most popular technique for wireless access. The technology development and standarization for multiple coverage ranges have made RF links the main option for point-to-point as well as broadcast applications. However, spectrum sharing can lead to throughput degradation on crowded environments, and regulations make it difficult to operate on new frequencies.

Optical wireless communications have experienced a huge improvement on the late years. The advances on solid-state lighting have awaken interest on the technology, as power budget is no longer an issue by using visible light communications (VLC) [1], [2]. LED-based lamps offer low-power consumption and long lifetime, and short switching times allow data transmission at significant rates for broadcast [3], [4]. Studies show ([5], [6]) that choosing an appropriate coding scheme data links can be implemented with minor modifications on the lamp's circuitry, and without affecting the performance of the lamps for illumination. This way, optical channels can be used as a complement or an alternative to existing RF links, and some characteristics (such as EMI immunity or light confinement) can be exploited to improve the behaviour for certain applications (enabling data transmission on sensitive environments or using various data links on different locations).

Combining the advantages from VLC with existing commercial devices, this paper presents the work in progress to develop a VLC demonstrator consisting on a portable user interface accesing a remote server via an optical downstream.

II. Optical Wireless

Optical wireless have some interesting properties that make it an interesting alternative for radiofrequency communications. Firstly, from infrared to visible wavelengths the spectrum is unlicensed. They are not subjected to strong regulations to keep potential threats under control (for both the human body and electrical equipment) like RF signals, apart from restrictions regarding, for example, the power emitted to ensure eye safety. Visible portion of the spectrum is largely harmless in terms of radiation damage and electromagnetic compatibility, while representing a huge unused bandwith (300 THz) when compared to the RF spectrum (300 GHz).

Optical radiation is confined to the room in which it is generated, securing transmissions against eavesdropping as they cannot be detected outside the coverage area. Also, this signals do not interfere with similar systems operating in other rooms. Finally, optical components are small and consume little power, which is important for mobile devices.

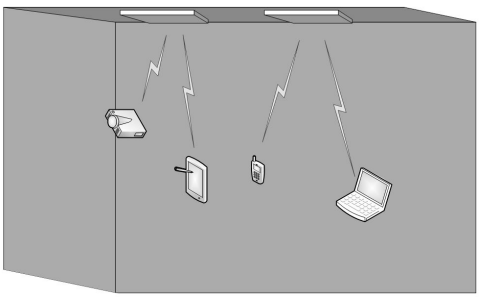

Fig. 1. VLC network

Visible Light Communications for in-house applications provide a partial solution to problems related to optical links, like the need of line-of-sight between transmitter and receiver. Lighting lamps offer a high power optical signal with high emission angle and broad coverage area, reducing the effects of the alignment and blocking problems. Main constrain to be considered for VLC systems is that communication

capabilities should not interfere with lamps' main function (illumination). Modulation must be chosen so that different average power values are possible to allow light dimming. Light intensity is usually controlled by pulse width modulation (PWM), so minor changes are needed to add data encoding schemes such as D-PPM with variable duty cycle. Other techniques, such as changing the modulation depth, require more complex driver circuits although offer better performance [7].

In solid-state lighting a white light source is made by combination of red, green and blue (RGB) emitters or by blue emitters and yellow phosphor (YB). Phosphor-based emitters have low-power consumption, high-illumination efficiency and low-production costs. However, the main drawback of this LEDs for communications is the slow temporal response of phosphor compared to the blue LED response, which results in a narrow bandwidth available for communications. Switching times for YB LEDs are around 150 ns, limiting the maximum frequency to values under 2,5 MHz [8]. On the other hand, RGB LEDs present an improved frequency response (up to tens of MHz for each emitter), but the modulation process is more complex and all three colors have to be controlled to avoid color flickering [9].

III. System Description

A. Application overview

The intended application consist on a light-weight portable terminal for accessing a remote computer running an X display manager, as shown in Fig. 2. Portable unit will run a X server communicating via XDMCP with the computer so the data channel is asymmetric, downloading large amounts of data over the downlink and sending user actions over the uplink. XDMCP has been chosen because of its ability to provide simultaneous access to multiple users and the existence of X servers for different platforms, enabling the use of multiple user interfaces. An e-book is been used for the portable unit, consisting on a 400 MHz microprocessor running a Linux-based operating system for easy software development. Its main characteristics are a 8.1 inches electronic paper display (768x1024 pixel resolution) with less than 400 grams weight. Using VLC to communicate with the main computer, this device acts like an input terminal to a full-size system with large processing capabilities.

This application is under development for in-house application, but the multiuser feature and low-cost scalability make the system suit other environments. Educational institutions could provide access to learning resources with low-cost terminals and avoiding expensive installation costs for wired dedicated systems. Data access could also be used in avionics or hospitals, where the EMI problem would be minimized by using optical wireless systems. In the first case, passenger reading lamps can provide data, audio or video applications using space division multiple-access techniques thanks to the reduced coverage area (passenger's seat). In the latter different applications could be implemented, like monitoring patients by means of several low-rate sensors and systems using OCDMA techniques.

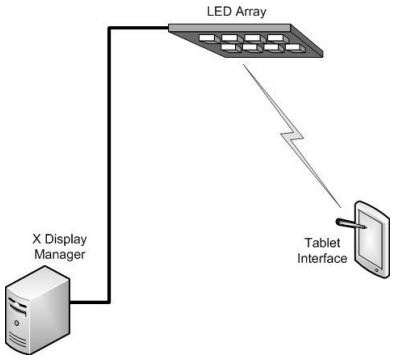

Fig. 2. Application overview

B. Coding scheme

Differential pulse-position modulation (D-PPM) is used for data transmission over the downlink, combined with PWM to allow different duty cycles. Coded data defines the pòsition of the pulse inside a symbol period, while desired illumination level is achieved by modifying the pulse width. Symbol period has been divided into 20 slots of 200 ns, 16 for acommodating a 4-PPM signal plus 4 guard slots to ensure transitions are possible. This way, illumination levels ranging from 5 to 95% of the lamp's nominal optical power will allow data broadcasting at a data rate of 1 Mbps. In Figure 3 the 4-bit combination for 3 (0011) is shown when the duty cycle is 10% and 90%.

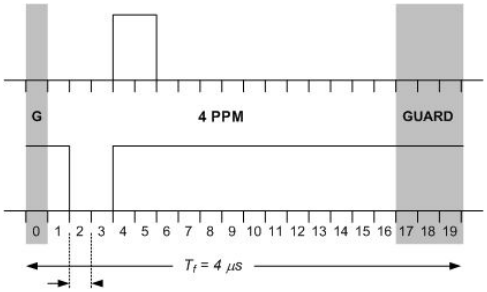

Fig. 3. Data representation for "0011"

Commercial-off-the-shelf (COTS) white LED lamps are used, although tests with RGB lamps will be conducted to study the maximum rate by using different simultaneous channels. Also, different alternatives will be studied for the uplink channel, considering low-data load (coming from human interface devices).

IV. Conclusions

The design of a visible light communications system have been shown, enabling remote access for in-house applications using commercial lighting systems based on white LEDs. The system allows sending data while providing illumination levels from 95% downto 5% of the lamp's nominal optical

power. Future work is oriented to test custom designed lamps based on RGB LEDs, measuring maximum rate achievable and implementing multiple channels.

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